

INTERACTION OF ANTS, PREDATORS AND THE SCALE INSECT, *PULVINARIELLA MESEMBRYANTHEMI*, ON *CARPOBROTUS EDULIS*, AN EXOTIC PLANT NATURALIZED IN WESTERN AUSTRALIA

By Leanne Collins and John K. Scott*

Department of Zoology, University of Western Australia, Nedlands 6009

Abstract

The scale insect *Pulvinariella mesembryanthemi* is host specific to the succulent *Carpobrotus edulis*, is tended by a range of ant species and is eaten by a species of coccinellid beetle. The host plant, scale and predators are exotic to Western Australia but the ants are native. Compared with control samples, more scale insects died when ants were removed and this appeared to be due to sooty mould infestation. The removal of predators had little effect on scale survivorship. For all treatments some scale survived to contribute offspring to the next generation. Independence from ants would allow this scale to colonize new areas but the formation of large populations of scale probably depends upon the presence of ants.

Introduction

Scale insects are well known for their ability to invade new habitats, particularly agricultural crops, and have been investigated mostly because of the harm they cause (Elton 1958; Miller and Kosztarab 1979). Scales are obligatory plant feeders, commonly forming mutualistic associations with ants (Way 1963) and are often eaten by coccinellid beetles (Hodek 1973). Obviously the complexity of the relationship between scales, host-plants, ants and predators will affect the ability of a scale to invade new habitats. In this paper we describe the interaction between a scale, host plant and a predator of the scale that have been introduced to Western Australia and native species of ant.

The succulent *Carpobrotus edulis* (L.) (Aizoaceae) is a native of South Africa but has been known from Western Australia since 1842 (Blake 1969) and is now naturalized in many coastal areas. The plant has a prostrate habit with fleshy leaves on branches which run along the ground. At the Marsupial Breeding Station, near Jandakot (32°10'S; 115°15'E), *C. edulis* is infested with the scale insect, *Pulvinariella mesembryanthemi* (Vallot) (Homoptera: Coccidae). The scale is probably host specific to *C. edulis* and appears to have migrated with the plant around the world. The scale is eaten by adults and larvae of *Cryptolaemus montrouzieri* Muls. (Coccinellidae), a species which was first introduced to Western Australia from eastern Australia in 1902 to control *Pseudococcus* species (Jenkins 1948). As far as known the ants found with the scales are native to Western Australia (J. D. Majer, pers. comm.).

In this paper we examine two aspects of the scales' population biology. Firstly, are ants necessary for the survival of the scale and secondly, what effect do the predators have on the population?

*Present address: Ent. Branch, Dept. of Agriculture, Jarrah Rd, S. Perth, W.A. 6151.

Species biology

The scale, *P. mesembryanthemi*, is known from a species of *Carpobrotus* from France (Pesson 1941) and more specifically from *C. edulis* in Argentina (Quintana 1956) and South Africa (Morrison and Rank 1957, p. 172; Peringuey 1892). The plant is distributed throughout southern Australia, southern Europe, California and South Africa (Blake 1969).

At the study site we examined the scales at irregular intervals between March 1979 and May 1980 and made the following observations. The scale had three or four generations. The first instar scale moved rapidly over all plant surfaces and presumably migrated to other plants. This was the only mobile instar and dispersal by this mechanism has been suggested by Quintana (1956). The first instar scales were inconspicuous on the plants and there may be a diapause or inactive stage over winter, as no second instar larvae were found between April and August. The second instar was immobile and was found exposed on leaves and also floral bracts when *C. edulis* was in flower. The second instar developed either into a male imago or into a third instar female which will eventually contain eggs. The females were immobile and progressively formed a white, waxy coat over their eggs. Upon death, the female body formed an additional part of the protective coat. The final generation females appeared in late March and in April. The eggs hatched soon after the death of the female. Males are the only winged form of this species (Pesson 1941) and the occurrence of males in colonies of scales varied from none to a high proportion in different locations at the study site.

The presence of scale insects seemed to affect the growth of the plants. Of 10 plants with scales, none had new growth in late March whereas 8 out of 10 plants without scales exhibited new growth (Fisher exact probability test, $p < 0.001$). There was no obvious scar left on the leaves where the scales had been feeding.

Two native species of ant tended the scale, *Crematogaster* sp. J.D.M. 33* and *Iridomyrmex* sp. J.D.M. 9*. The ants were present throughout both the day and night, soliciting honeydew by caressing the back of the scale with their antennae. The two ant species occurred in mutually exclusive areas.

Not all populations of scale were tended by ants. One population which was not tended during our observations was known to have been tended by an ant species, *Iridomyrmex conifer* Forel, two years previously. This population of ants moved from the study area due to a scarcity of food (nectar) brought about by three successive years of drought (P. McMillan, pers. comm.). The scales remaining in this area were not tended by ants but bees were frequently observed removing honeydew from the scales. In the absence of ants and bees, the scales were observed to remove honeydew

* Voucher specimens of the ants are housed in Dr J. D. Majer's collection at the Western Australian Institute of Technology.

by the active expulsion of droplets. These droplets landed about five millimetres away from the body of the scales which expelled the droplets.

The coccinellid, *C. montrousieri*, was the predator of the scale at the study site. This predator was always present with the populations of the scale although the species is known to eat other Homoptera at the study site. When the adult predator approaches the scale insect it first solicits the release of honeydew in a manner similar to that of the ants that tend this species. The predator eats the scale after consuming the honeydew. Any remaining part of the dead scale drops off the plant. The larva of the coccinellid is also predatory and eats its way into the remains of the female body which contains the eggs and proceeds to eat the eggs from the inside.

Two species of parasite could be distinguished within the scales at the study site. These have not been identified although the scale is known to have a number of parasites in South Africa and Argentina (Peringuey 1892; Quintana 1956).

Methods

The plants used in the experiments were infested only with female scales. We removed ants, predators or both ants and predators from 5 branches for each experiment and used 5 nearby branches as controls. The branches in the four treatments did not differ statistically in leaf number and in wet weight at the end of the experiment (Table 1). The branches were not inter-twined with other plant material and were spread along the ground.

TABLE 1

Mean \pm standard error with range in parenthesis of the number of leaves and the wet weight of branches (with leaves). Sample size is 5 in each case. Analysis of variance on number of leaves and wet weight of branches showed no differences.

Treatment	Number of leaves	Weight of branches (gm)
Control	46.0 \pm 5.79 (32-62)	116.9 \pm 18.0 (62.2-172.6)
Ants excluded	69.6 \pm 17.13 (38-124)	203.0 \pm 52.04 (66.8-360.7)
Predators excluded	49.2 \pm 12.53 (18-94)	170.5 \pm 43.21 (70.7-328.5)
Ants and predators excluded	34.6 \pm 5.13 (22-53)	103.1 \pm 27.56 (60.2-211.0)

Ants were excluded from branches by placing cloth sheets between the branch and the ground. The cloth edges and stem of the plant at the edge of the cloth were covered with grease. The edge of the cloth was secured to the ground. All leaves and other material which could form a bridge for the ants to the experimental area were removed and ants within the experimental area were removed by hand.

Predators were excluded from the plants by placing netting of 2 mm mesh over the plants. The circumference of the netting was pegged into the ground and the netting raised, tent-like, above the experimental area. All predators were removed by hand from within this area however, ants were observed to pass through the mesh to tend the scales.

The above methods were combined to exclude both ants and predators. The 5 control branches were left unaltered.

Each branch was examined 6 times over a period of 18 days in April and during these visits we counted scales and checked that the experimental exclusions were successful. At the start of the experiment we counted second instar scales. The branches did not have overlapping generations and the experiment ceased when first instar larvae emerged from the egg cases. Thus the final number of scales were those that will contribute young to the next generation.

Results

There were wide differences in the mortality of scales among the treatments, with more scales dying when both ants and predators were removed (Table 2). However the number of scale in the control treatment also decreased over the time we observed the scales. We suspected that uncontrolled factors such as parasites could be responsible. To account for these changes over time we used analysis of covariance to compare the treatments (Li 1964). Regressions were calculated with the percentage of the original number of scales surviving as the dependent variable (Y 's) (arcsine transformed, in radians) and time (in days since the start of the experiment) as the independent variable (X 's). Analysis of covariance was then used to compare the slopes of the regressions and the adjusted mean percentage of surviving scale (based on the overall mean sample day). The

TABLE 2
Mean \pm standard error with range in parenthesis of the original number of scales, the final number of scales, and the percentage survivorship. Sample size is 5 in each case.

Treatment	Original number of scales	Final number of scales	Percentage surviving
Control	54.8 \pm 5.95 (36-68)	20.2 \pm 6.58 (9-46)	37.0 \pm 9.78 (22.1-74.2)
Ants excluded	58.2 \pm 6.51 (38-69)	7.0 \pm 0.84 (5-9)	13.0 \pm 2.82 (8.0-23.7)
Predators excluded	55.2 \pm 6.28 (32-70)	21.2 \pm 2.76 (15-31)	40.7 \pm 6.95 (25.0-59.4)
Ants and predators excluded	104.4 \pm 15.5 (54-151)	10.8 \pm 2.91 (3-19)	9.8 \pm 1.94 (5.5-15.3)

TABLE 3

Analysis of covariance of the percentage of scales surviving among experimental treatments. The percentages (arcsine transformed) of the surviving scales (Y) were regressed against time, in days (X). Y 's are adjusted to $X = 9.2$ days. Results of analysis of covariance: $F = 443.13$, $p < 0.001$ that the overall regression $\beta = 0.0$; $F = 3.22$, $p < 0.05$ that $\beta_1 = \beta_2 = \dots$; $F = 13.95$, $p < 0.001$ that $Y_1 = Y_2 = \dots$. Sample size is 30 for each regression.

Treatment	Regression equation	r^2	Probability $\beta = 0.0$	Adjusted Y	Adjusted % of surviving scales
Control	$Y = 1.50 - 0.05X$	0.73	< 0.001	1.02	85.2
Ants excluded	$Y = 1.44 - 0.07X$	0.88	< 0.001	0.85	75.1
Predators excluded	$Y = 1.56 - 0.05X$	0.77	< 0.001	1.13	90.4
Ants and predators excluded	$Y = 1.53 - 0.07X$	0.79	< 0.001	0.92	80.0

results of this analysis are given in Table 3. There were differences among the slopes of the treatments due to a greater mortality rate for the two treatments where ants were removed. Similarly the adjusted percentages of surviving scales were lower where ants were removed. Obviously the scale benefited from the presence of the ants but from a comparison of individual regressions there was no difference between the control and the sample where the predator only was removed. The scales had sooty mould infestations in treatments where the ants had been removed. The mould appeared to be growing on honeydew and was probably the cause of the differences in mortality rates.

Discussion

Ants have often been observed to remove honeydew from scales thus preventing the growth of sooty mould (Way 1963). Our experiment indicates that the removal of honeydew may be more important for survival than the actions of predators. However the ability of some scale to survive without ants would seem to be an important attribute of a species capable of colonizing new areas. That the scale can expel honeydew away from their bodies indicates that tending by ants may not be necessary but this probably depends on the density of scale. When scales are closely packed an expelled drop of honeydew could land on another scale. Further experiments on the relationship between these scale and ants would need to take density into account.

C. montrouzieri, is a well known predator of homoptera and has been used widely as a biological control agent (Barlett 1973; Hodek 1973). Often this insect needs to be mass-reared for release to ensure a sufficiently large number to effect control of insects, chiefly mealybugs (*Pseudococcus* spp.). In our example this predator may have been too low in numbers to affect the scale or the scale may not have been the preferred prey. The predator may also be more important at another time of the year but more experimentation would be needed to show this.

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BOOK REVIEW

Guide to the aquatic insects of New Zealand by Michael J. Winterbourn and Katharine L. D. Gregson. 1981. *Bull. ent. Soc. N.Z.* 5. 80 pages, 222 text-figs (100 of whole animals). Price NZ\$9.00 (overseas orders add \$1.00 for surface postage); educational institutions ordering 5 or more copies, \$7.00 each.

The principal content of this handbook is illustrated keys to the fauna of aquatic and water-associated insects found in New Zealand. It covers the stages usually found by collectors in or on water bodies, i.e. the immature stages, plus (for Coleoptera and Hemiptera) the adults. Where possible insects have been identified to genera and species, but sometimes identification has been possible only to the family level. Annotated notes on distribution, habitat, and taxonomic problems are incorporated in the keys. A list of 152 references is given to the main taxonomic and biological literature. There are brief notes on the collection, preservation and curation of specimens, and a glossary and a complete index. The illustrations are of a high standard and form an important role in complementing the text.

There is no doubt that this handbook will appeal to a wide readership: specialists in all parts of the world will find the keys, taxonomic notes, and references to all the aquatic insects of New Zealand in one publication of great use, while others such as naturalists and biology students will find that they can identify (often to species level) the specimens they collect or wish to study. It is an essential text that every New Zealand amateur and professional entomologist cannot afford to be without and one that Australian persons interested in aquatic insects should also seriously consider purchasing.

Orders for this bulletin should be sent to either: Mrs B. M. May, Distributions Secretary, Entomological Society of N.Z., 6 Ocean View Rd, Huia, New Zealand (make remittances payable to "Entomological Society of N.Z."), OR: Dr J. A. Robb, Secretary/Treasurer, N.Z. Limnological Society, c/- Christchurch Drainage Board, P.O. Box 13006, Christchurch, New Zealand (make remittances payable to "N.Z. Limnological Society").

M. S. MOULDS